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54 **Dental restorative compositions.**

57 Two-paste dental restorative compositions cured by a free-radical-generating peroxide/amine redox combination contain either or both of ethoxylated bisphenol A dimethacrylate and propoxylated bisphenol A dimethacrylate, optionally blended with bisphenol A/glycidyl methacrylate adduct, as a monomeric matrix and one or more inorganic fillers selected from strontium aluminium borosilicate, barium aluminium silicate, barium aluminium borosilicate and mixtures thereof.

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1 DENTAL RESTORATIVE COMPOSITIONS
DESCRIPTION

This invention relates to dental restorative materials. Since dentistry was first practised, dentists
5 and patients alike have sought the ideal restorative material and the search still continues. The literature shows that many innovations have been published and patented, some of much greater significance than others.

However, within the past decade, composite materials based upon vitreous filled combinations of acrylic functional monomers, pioneered by R.L. Bowen and described in U.S. Patent Specification 3,006,112, have
10 gained both professional and public acceptance and have proliferated in ever-increasing variations. Within this
15 proliferation, certain desirable and virtually essential characteristics have become generally recognised and established, namely, (i) two-paste equi-ratio mixing, (ii) pre-shaded compositions for easy placement preparation, (iii) a sufficient radiopaque filler content to
20 enable certain radiographic detection to be effected, (iv) adequate shelf stability, (v) physical properties approaching or even exceeding those of human tooth enamel and (vi) relative ease of finishing.

One characteristic of restorative compositions,
25 which is highly desirable when used for anterior restorations and is virtually essential when used for posterior restorations, especially in occlusal load-bearing loca-

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1 tions, is sufficient abrasion-resistance to ensure
maintenance of reasonable anatomical form for a
duration of several years. Compared with the abrasion
resistance of the better amalgam restorations, this
5 characteristic has generally remained elusive during
more than 15 years of development of dental composites.
While masticatory forces normally serve to burnish and
polish the occlusal surface of amalgam restorations,
in the case of composite restorations, a two-phase
10 erosion pattern is observable, whereby progressive
erosion of the polymeric matrix results in eventual
dislodgement of filler particles and this exposes new
areas of the matrix to the erosion process.

In order to retard this erosion process
15 significantly, changes in the characteristics of both
the polymeric and vitreous phases appear to be necessary.
The polymeric phase should remain relatively
rigid, yet be less brittle and therefore tougher. This
predicates monomer molecules of fairly rigid structure,
20 low polymerization shrinkage and optimum crosslinking
density. The filler particles should be of optimum
particle size distribution for maximum volume fraction
packing, have adequate hardness yet not be brittle and
should closely match the refractive index of both tooth
25 enamel and the polymeric matrix to ensure reasonable
aesthetic appeal.

Traditionally, the vast majority of composite
dental restoratives have embodied a monomeric matrix
consisting of BisGMA resin, i.e. bisphenol A/glycidyl
30 methacrylate adduct resin, diluted to a suitable
viscosity with one or more diacrylate functional monomers.
Most of these diluent monomers are of relatively
low molecular weight, resulting in high polymerization
shrinkage, high crosslinking density and brittleness
35 due to residual matrix stress and high modulus, even-

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1 tually forming micro-cracks. Following later work,
R.L. Bowen reported the synthesis of a liquid
eutectic monomer blend based on isomeric phthaloyl
dimethacrylates, but as yet this has not achieved
5 commercial utility due to several inherent disadvantages.

There is thus a continuing need for
improved abrasion-resistant dental composites which
overcome the above-noted disadvantages and this
10 invention seeks to provide such improved dental
composites, advantageously in the form of two-paste
systems.

The use of crystalline monomers, wholly or
as diluents for BisGMA resin, has received little
15 attention, particularly the use of crystalline monomers
of closely-related structure and molecular weight.
It has surprisingly been discovered that both ethoxylated
and propoxylated bisphenol A dimethacrylates can
be obtained in a very pure crystalline state, by
20 reacting bisphenol A with either ethylene or propylene
carbonate as appropriate, followed by esterification,
though slight traces of impurities cause liquification
at ambient temperature due to their low melting point.
When optionally blended in widely variable proportions
25 with BisGMA resin at slightly elevated temperature,
dissolution occurs and the resulting solution remains
stable with respect to freedom from crystal deposition,
even after prolonged refrigeration. Furthermore,
following easy and rapid ambient temperature copoly-
30 merization, a tough moderately-crosslinked fracture-
resistant polymer results, with low attendant polymerization
shrinkage.

According to one aspect of this invention,
therefore, a dental restorative composition is provided,
35 which is curable by means of a free-radical-generating

1 peroxide/amine redox combination and comprising an
acrylic functional monomer and at least one filler
material, which is characterized in that the monomer
comprises at least one alkoxyated bisphenol A
5 dimethacrylate and that the filler material is selected
from strontium aluminium borosilicate, barium aluminium
silicate, barium aluminium borosilicate and mixtures
thereof.

The compositions of the present invention
10 may advantageously include either or both of ethoxy-
lated and propoxylated bisphenol A dimethacrylates,
alone or in combination with BisGMA resin, but they do
not comprise BisGMA resin alone. A desired concen-
tration of ethoxylated or propoxylated bisphenol A
15 dimethacrylate, alone or in combination, is in the range
from 15 to 30 weight percent. The BisGMA is preferably
present, when used, in concentrations of up to 15 weight
percent.

If one of the above monomers or a blend of the
20 two monomers of suitable viscosity is then highly
loaded with fillers of optimal particle size distri-
bution, chosen from the aforementioned particulate
materials of suitable modulus and refractive index,
together with the necessary catalyst and accelerator
25 components plus optional pigments and stabilizers, a
two-paste system can be formulated which, when adequately
polymerized, exhibits abrasion resistance superior to
that of all known commercial systems presently in use.
A suitable size distribution for the filler particles
30 is from 0.02 to 30 microns, with approximately 50 weight
percent of the particles preferably being in the 1.0
to 10.0 micron size range. The filler material may
typically be present as a single material or as a mix-
ture of materials in a total concentration of 70 to 85
35 weight percent. The two pastes are normally always

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- 1 spatulated together, to initiate the redox reaction,
which results in polymerization and setting of the
material.

- Two typical examples of such two-paste
5 systems are as follows:

EXAMPLE 1

CATALYST PASTE

ethoxylated bisphenol A dimethacrylate monomer
BisGMA resin

- 10 benzoyl peroxide catalyst
UV absorber
submicron silicon dioxide
strontium aluminium borosilicate filler

BASE PASTE

- 15 ethoxylated bisphenol A dimethacrylate monomer
BisGMA resin
tertiary amine accelerator
submicron silicon dioxide
barium aluminium borosilicate
20 UV absorber
pigments

EXAMPLE 2

CATALYST PASTE

ethoxylated bisphenol A dimethacrylate monomer

- 25 benzoyl peroxide catalyst
UV absorber
submicron silicon dioxide
strontium aluminium borosilicate filler

BASE PASTE

- 30 propoxylated bisphenol A dimethacrylate monomer
tertiary amine accelerator
UV absorber
pigments
submicron silica
35 barium aluminium silicate filler

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1 A variety of synthetic vitreous materials
based on melts containing substantial amounts of alumina
and silica, plus a sufficient quantity of at least one
metallic oxide designed to impart radiopacity, are
5 preferred. Fused alumina possesses the necessary
abrasion resistance, but is of unsuitable refractive
index and is essentially nonradiopaque. Many porcelain
tooth glazes also possess the necessary abrasion resis-
tance and refractive index, but are essentially non-
10 radiopaque. A combination of submicron silica and
polymeric filler yields a composite which can be
polished almost as smooth as amalgam, but has very
poor abrasion resistance, though it is used commercially
in at least two anterior restorative formulations. The
15 submicron silica may typically be present in a concen-
tration of up to 10 weight percent. It has been
discovered that radiopaque fillers of vitreous materials
containing substantial amounts of barium or strontium
oxide fused with appropriate quantities of alumina and
20 silica to yield stable leach-resistant glasses are
particularly suitable for use with the above-described
monomers.

The following are further Examples of various
compositions falling within the scope of the present
25 invention. The percentages listed in the Examples are
by weight:

EXAMPLE 3

A two-paste filled composite restorative material
based on the standard peroxide/amine curing system and
30 having the following final mix composition was prepared
by mixing and reacting the ingredients by spatulation:

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1	ethoxylated bisphenol A dimethacrylate	10.475.
	bisphenol A/glycidyl methacrylate adduct	10.475
	benzoyl peroxide	0.23
	tertiary amine	0.20
5	UV absorber	0.10
	2,6-di-tertiary-butyl-para-cresol	0.02
	strontium aluminium borosilicate	<u>78.50</u>
		100.00

An abrasion rate of 1.46 microlitres/hour
 10 was measured for this material seven days from the
 time of mixing.

EXAMPLE 4

A similar two-paste composite material
 utilizing a peroxide/amine curing system and having
 15 the following final mix composition was prepared in
 a manner similar to that set forth in Example 3.

	bisphenol A/glycidyl methacrylate adduct	16.60
	triethylene glycol dimethacrylate (inhibited)	2.27
	butylene glycol dimethacrylate (inhibited)	2.09
20	tertiary amine	0.25
	UV absorber	0.20
	benzoyl peroxide	0.09
	strontium aluminium borosilicate	<u>78.50</u>
		100.00

25 This composition gave an increased abrasion
 rate of 1.81 microlitres/hour, measured seven days from
 the time of mixing, compared with the materials of
 Example 3.

EXAMPLE 5

30 Another peroxide/amine cured two-paste com-
 posite material was prepared, having the following
 final mix composition, in a manner similar to that set
 forth in Example 3:

35

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1	propoxylated bisphenol A dimethacrylate	21.50
	benzoyl peroxide	0.25
	tertiary amine	0.25
	UV absorber	0.10
		0.02
5	2,6-di-tertiary-butyl-para-cresol	0.75
	FD&C-approved pigment	1.50
	submicron silicon dioxide	75.63
	strontium aluminium borosilicate	100.00

- 10 This material gave an abrasion rate of 1.55 microlitres/hour, measured seven days from the time of mixing, which was not significantly different from the material of Example 3.

EXAMPLE 6

15	A further peroxide/amine cured two-paste composite material, having the following final mix composition, was prepared in a manner similar to that set forth in Example 3.	
	ethoxylated bisphenol A dimethacrylate	18.69
	benzoyl peroxide	0.30
20	tertiary amine	0.28
	UV absorber	0.09
	2,6-di-tertiary-butyl-para-cresol	0.02
	submicron silicon dioxide	1.39
	barium aluminium silicate	41.10
25	strontium aluminium borosilicate	38.13
		100.00

- 30 This composition gave a significantly reduced abrasion rate of 1.12 microlitres/hour, measured seven days from the time of mixing, when compared with the material of Example 3.

EXAMPLE 7

- 35 An additional peroxide/amine cured two-paste composite material, having the following final mix composition, was prepared in a manner similar to that

1 set forth in Example 3:

	ethoxylated bisphenol A dimethacrylate	21.50
	benzoyl peroxide	0.30
	tertiary amine	0.30
5	UV absorber	0.10
	2,6-di-tertiary-butyl-para-cresol	0.02
	submicron silicon dioxide	1.50
	strontium aluminium borosilicate	<u>76.28</u>
		100.00

10 This material gave an abrasion rate of 1.31 microlitres/hour, measured seven days from the time of mixing, which was not significantly different from the material of Example 3.

EXAMPLE 8

15 Another peroxide/amine cured two-paste composite material, having the following final mix composition, was prepared in a manner similar to that set forth in Example 3:

	ethoxylated bisphenol A dimethacrylate	25.34
20	benzoyl peroxide	0.39
	tertiary amine	0.275
	UV absorber	0.115
	2,6-di-tertiary-butyl-para-cresol	0.025
	submicron silicon dioxide	8.08
25	strontium aluminium borosilicate	31.025
	barium aluminium silicate	<u>34.75</u>
		100.00

An abrasion rate of 1.09 microlitres/hour was measured for this material, seven days from the time of mixing.

30 These examples show not only the scope of the present invention, compared to previously-mentioned commercially-available materials, but also the effects of compositional variations on the abrasion rate of the
35 respective materials.

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1 Many compounds may be used as typical
ingredients serving the functions of catalyst,
accelerator and inhibitor and/or UV absorber com-
ponents, such as:

5

CATALYSTS

dibenzoyl peroxide

lauryl peroxide

benzoyl acetyl peroxide

10 dicyclohexyl peroxide

ACCELERATORS

dimethyl-para-toluidine

diethyl-para-toluidine

dihydroxyethyl-para-toluidine

15 N,N-dimethyl-3,5-xylidine

para-(dimethylamino)-phenylacetic acid

INHIBITORS

hydroquinone monomethyl ether

2,6-di-tertiary-butyl-para-cresol

20 2-tertiary-butyl-4-methoxyphenol

3-tertiary-butyl-4-methoxyphenol

The catalysts, accelerators and inhibitors
may typically be present in concentrations of up to
1.0 weight percent. Other additives, such as UV
25 absorbers, are typically present in concentrations of
up to 0.5 weight percent.

Very many different polymeric matrix and
filler combinations have been investigated with respect
to abrasion resistance, using a "protomatic" toothbrush
30 abrasion machine, fitted with Colgate-Palmolive "medium"
toothbrush heads, running in a simulated toothpaste
slurry at 140 strokes per minute, with a fixed load of
220 grams and a stroke of 5.7 cm (2.25 inches) for a
total of 67,200 strokes per specimen, over a swept area
35 of 9.7 cm (1.5 square inches). The results obtained

1 for six commercial composite restoratives and the best
 six materials (Examples 3 - 8) of the present inven-
 tion were as follows:

TABLE

5			Microlitres/ hour
			Abrasion Rate**
	"Silar" * (Microfilled)	3M Company	19.80
	"Vytol" *	L.D.Caulk Co.	3.33
	"Profile" *	S.S.White	2.34
10	"Simulate" *	Sybron/Kerr	2.17
	"Concise" *	3M Company	2.15
	"Adaptic" * (Radiopaque)	J & J	1.95
	Strontium glass/BISGMA/TEGMA/BGMA		1.81
	Strontium glass/EBPADMA		1.55
15	Strontium glass/EBPADMA/BISGMA		1.46
	Strontium glass/EBPADMA		1.31
	Strontium glass/barium aluminosilicate/EBPADMA		1.12
	Strontium glass/barium aluminosilicate/EBPADMA		1.09

* Trademark of respective company listed in Table

20 ** Measured seven days from time of mixing

It is readily seen that the abrasion
 resistance of commercial composites varies considerably
 and even the worst have been claimed to be satisfactory
 in clinical studies using anterior teeth and selected
 25 classes of cavity. Among the materials of the present
 invention, namely the last six materials listed in the
 Table, it can be seen that for a given filler system the
 abrasion resistance is always greater for the polymeric
 matrixes of this invention and that the commercially
 30 available radiopaque vitreous fillers utilized indicate
 that strontium-containing fillers generally exhibit
 superior abrasion resistance.

1 CLAIMS:

1. A dental restorative composition curable
by means of a free-radical-generating peroxide/amine
redox combination and comprising an acrylic functional
5 monomer and at least one filler material,
characterised in
that the monomer comprises at least one alkoxyated
bisphenol A dimethacrylate and that the filler material
is selected from strontium aluminium borosilicate,
10 barium aluminium silicate, barium aluminium borosilicate
and mixtures thereof.
2. A dental restorative composition according
to claim 1, wherein the monomer comprises ethoxylated
bisphenol A dimethacrylate.
- 15 3. A dental restorative composition according
to claim 1 or 2, wherein the monomer comprises propoxy-
lated bisphenol A dimethacrylate.
4. A dental restorative composition according
to claim 1, 2 or 3, wherein the monomer is either or both
20 of ethoxylated bisphenol A dimethacrylate and propoxy-
lated bisphenol A dimethacrylate blended with bis-
phenol A/glycidyl methacrylate adduct.
5. A dental restorative composition according
to any preceding claim, which comprises 15-30 weight
25 percent of ethoxylated bisphenol A dimethacrylate and/or
propoxylated bisphenol A dimethacrylate blended with
bisphenol A/glycidyl methacrylate adduct and 70-85 weight
percent of the filler material.
6. A cured composite dental restoration
30 composition comprising an acrylic functional monomer
and at least one filler material,
characterised in
that the cured composition consists essentially of:
(a) 15-30 weight percent of at least one
35 material selected from ethoxylated bisphenol A dimeth-

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- 1 acrylate and propoxylated bisphenol A dimethacrylate;
 (b) up to 15 weight percent of bisphenol
 A/glycidyl methacrylate adduct;
 (c) an activator;
 5 (d) a catalyst;
 (e) 70-85 weight percent of filler material
 selected from strontium aluminium borosilicate, barium
 aluminium silicate, barium aluminium borosilicate and
 mixtures thereof.
- 10 7. A cured two-paste filled composite
 restorative material based on the standard peroxide/
 amine curing system and having the following final
 mix composition by weight:
- | | | |
|---|---|----------------|
| ethoxylated bisphenol A dimethacrylate |) | |
| 15 bisphenol A/glycidyl methacrylate adduct |) | 15-30 combined |
| benzoyl peroxide | | 0.1-1.0 |
| tertiary amine | | 0.1-1.0 |
| UV absorber | | 0.05-0.50 |
| 2,6-di-tertiary-butyl-para-cresol | | 0.01-0.10 |
| 20 strontium aluminium borosilicate |) | |
| barium aluminium borosilicate |) | 70-85 combined |
| TOTAL | | 100.00 |
8. A cured two-paste composite material
 having the following final mix composition by weight:
- | | | |
|--|--|-----------|
| 25 propoxylated bisphenol A dimethacrylate | | 15-30 |
| benzoyl peroxide | | 0.1-1.0 |
| UV absorber | | 0.05-0.50 |
| 2,6-di-tertiary-butyl-para-cresol | | 0.01-0.10 |
| submicron silicon dioxide | | 1.0-10.0 |
| 30 barium aluminium silicate | | 70-85 |
| TOTAL | | 100.00 |
9. A peroxide/amine cured two-paste
 composite material having the following final mix
 composition by weight:

35

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1	ethoxylated bisphenol A dimethacrylate	15-30
	benzoyl peroxide	0.1-1.0
	tertiary amine	0.1-1.0
	UV absorber	0.05-0.50
5	2,6-di-tertiary-butyl-para-cresol	0.01-0.10
	submicron silicon dioxide	1.0-10.0
	barium aluminium silicate	70-85 combin-
	strontium aluminium borosilicate)	ed
	TOTAL	100.00

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